Broad Brook

Watershed Summary

WATERSHED DESCRIPTION AND MAPS

The Broad Brook watershed covers an area of approximately 10,478 acres in the southeastern corner of Connecticut (Figure 1). There are four municipalities located at least partially in the watershed, including Preston, Griswold, Lisbon, and North Stonington, CT.

The Broad Brook watershed includes one segment impaired for recreation due to elevated bacteria levels (CT3716-00_01). This segment was assessed by Connecticut Department of Energy and Environmental Protection (CT DEEP) and included in the CT 2010 303(d) list of impaired waterbodies. Some segments in the watershed were currently unassessed as of the writing of this document. This does not suggest that there are no issues on these segments, but indicates a lack of current data to evaluate the segments as part of the assessment process. An excerpt of the Integrated Water Quality Report is included in Table 1 (CT DEEP, 2010).

The entire segment of Broad Brook (CT3716-00_01) is impaired for bacteria. Broad Brook begins at the outlet of the Lewis Pond Dam just north of the intersection of Lewis Road and Route 165 (Shetucket Turnpike) in Preston, flows northwesterly through Preston, is joined by multiple tributaries, including Hollowell Brook, Ayers Brook, and Sheep Barn Brook, and empties into the Quinebaug River at the border of Preston, Lisbon, and Griswold (Figures 2 and 5). Broad Brook flows through land characterized by a mix of forested and agricultural land uses (Figure 4).

The impaired segment of Broad Brook has a water quality classification of A. Designated uses include potential drinking water supply, habitat for fish and other aquatic life and wildlife, recreation, and industrial and agricultural water supply. Broad Brook is impaired due to elevated bacteria concentrations, affecting the designated use of recreation. As there are no designated beaches in this segment of the Broad Brook, the specific recreation impairment is for non-designated swimming and other water contact related activities.

Impaired Segment Facts

Impaired Segment: Broad Brook (CT3716-00_01)

Municipality: Preston

Impaired Segment Length (miles): 4.73

Water Quality Classifications: Class A

Designated Use Impairments: Recreation

Sub-regional Basin Name and Code: Broad Brook, 3716

Regional Basin: Quinebaug

Major Basin: Thames

Watershed Area (acres): 10,478

MS4 Applicable? No

Figure 1: Watershed location in Connecticut

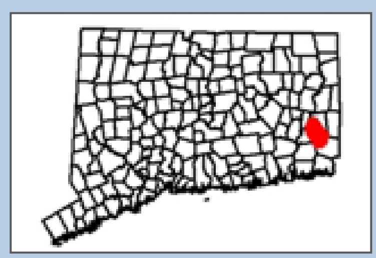
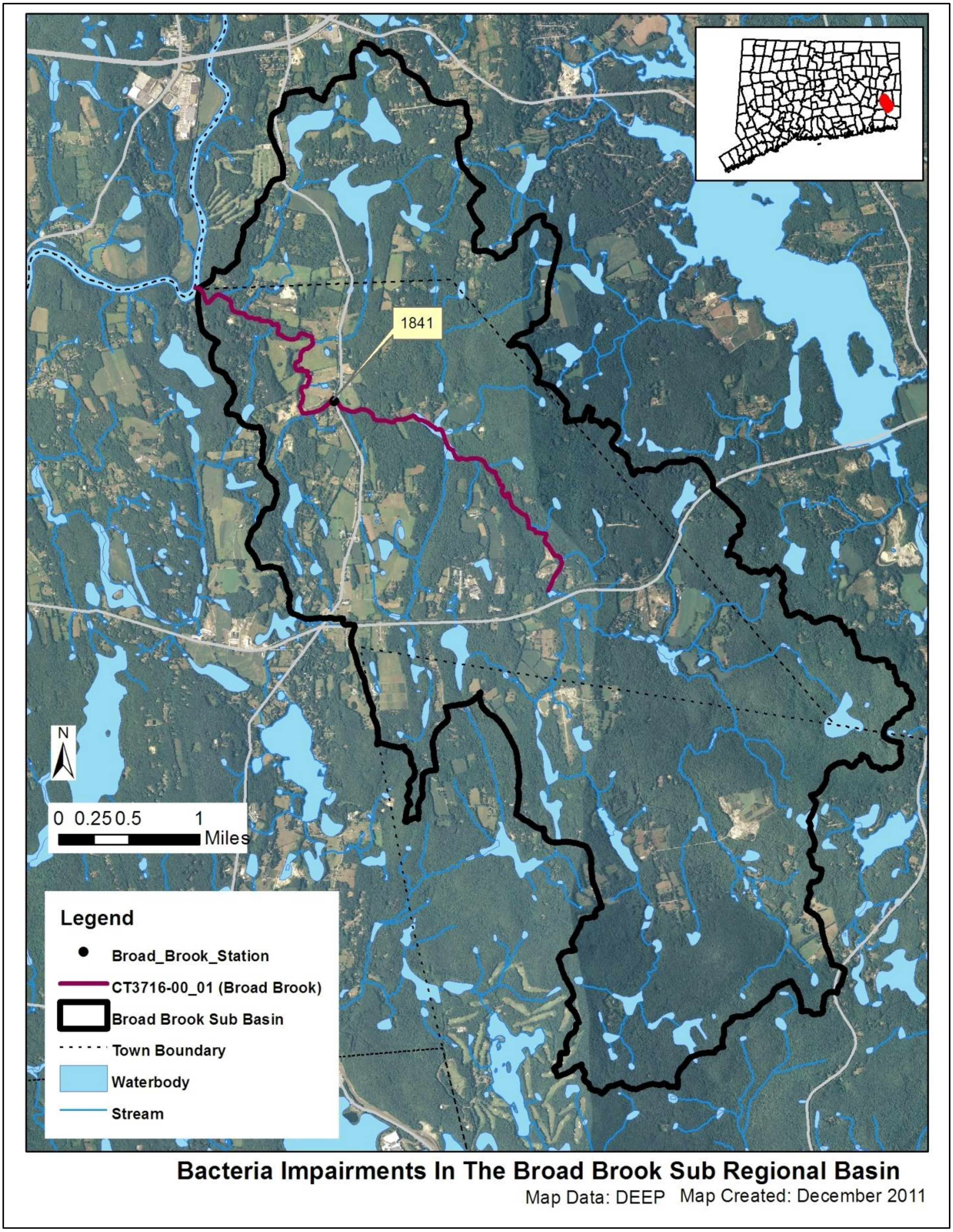


Table 1: Impaired segments and nearby waterbodies from the Connecticut 2010 Integrated Water Quality Report

Waterbody ID	Waterbody Name	Location	Miles	Aquatic Life	Recreation	Fish Consumption
CT3716-00_01	Broad Brook (Preston)-01	From mouth at confluence with Quinebaug River (DS of Old Jewett City Road crossing), at the Preston/Lisbon/Griswold borders, US to Lewis Pond outlet dam (north side of Route 165, near intersection with Lewis Road), Preston.	4.73	NOT	NOT	FULL
Shaded cells indicate impaired segment addressed in this TMDL **FULL = Designated Use Fully Supported** **NOT = Designated Use Not Supported** **U = Unassessed**						

Figure 2: GIS map featuring general information of the Broad Brook watershed at the sub-regional level



Land Use

Existing land use can affect the water quality of waterbodies within a watershed (USEPA, 2011c). Natural processes, such as soil infiltration of stormwater and plant uptake of water and nutrients, can occur in undeveloped portions of the watershed. As impervious surfaces (such as rooftops, roads, and sidewalks) increase within the watershed landscape from commercial, residential, and industrial development, the amount of stormwater runoff to waterbodies also increases. These waterbodies are negatively affected as increased pollutants from nutrients and bacteria from failing and insufficient septic systems, oil and grease from automobiles, and sediment from construction activities become entrained in this runoff. Agricultural land use activities, such as fertilizer application and manure from livestock, can also increase pollutants in nearby waterbodies (USEPA, 2011c).

As shown in Figures 3 and 4, the Broad Brook watershed consists of 66% forests, 16% agriculture, 11% urban areas, and 5% water. Though some agriculture is found throughout the watershed, most agricultural operations are concentrated in the western portion of the watershed near the impaired segment. Forested areas include the Pachaug State Forest in the southern portion of the watershed. Urban areas are spread throughout the watershed and typically follow major highways (Figure 4).

Figure 3: Land use within the Broad Brook watershed

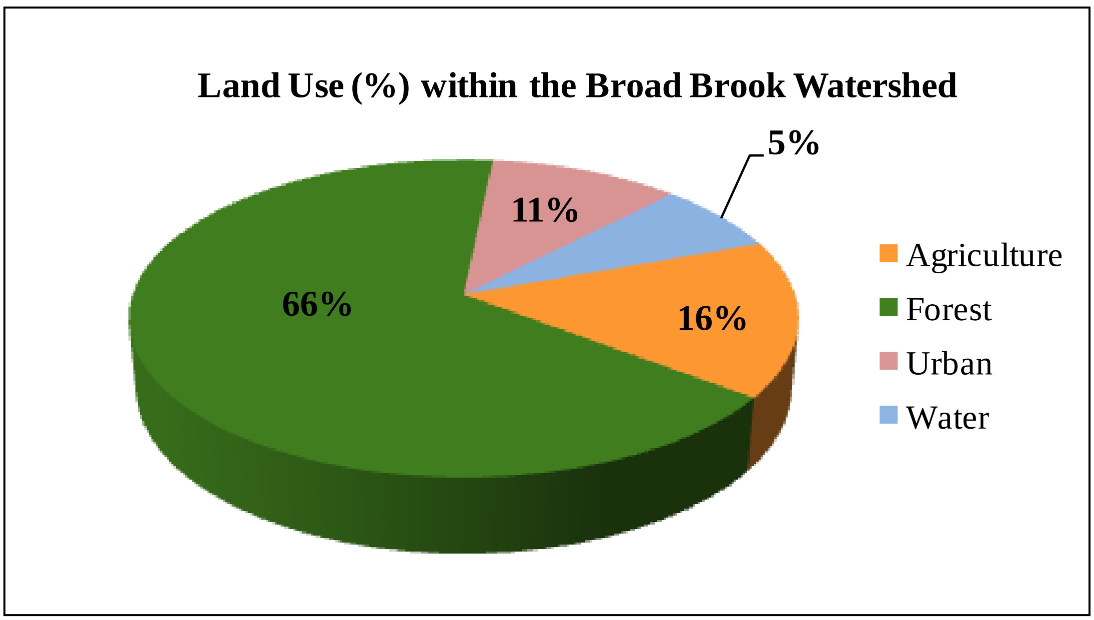
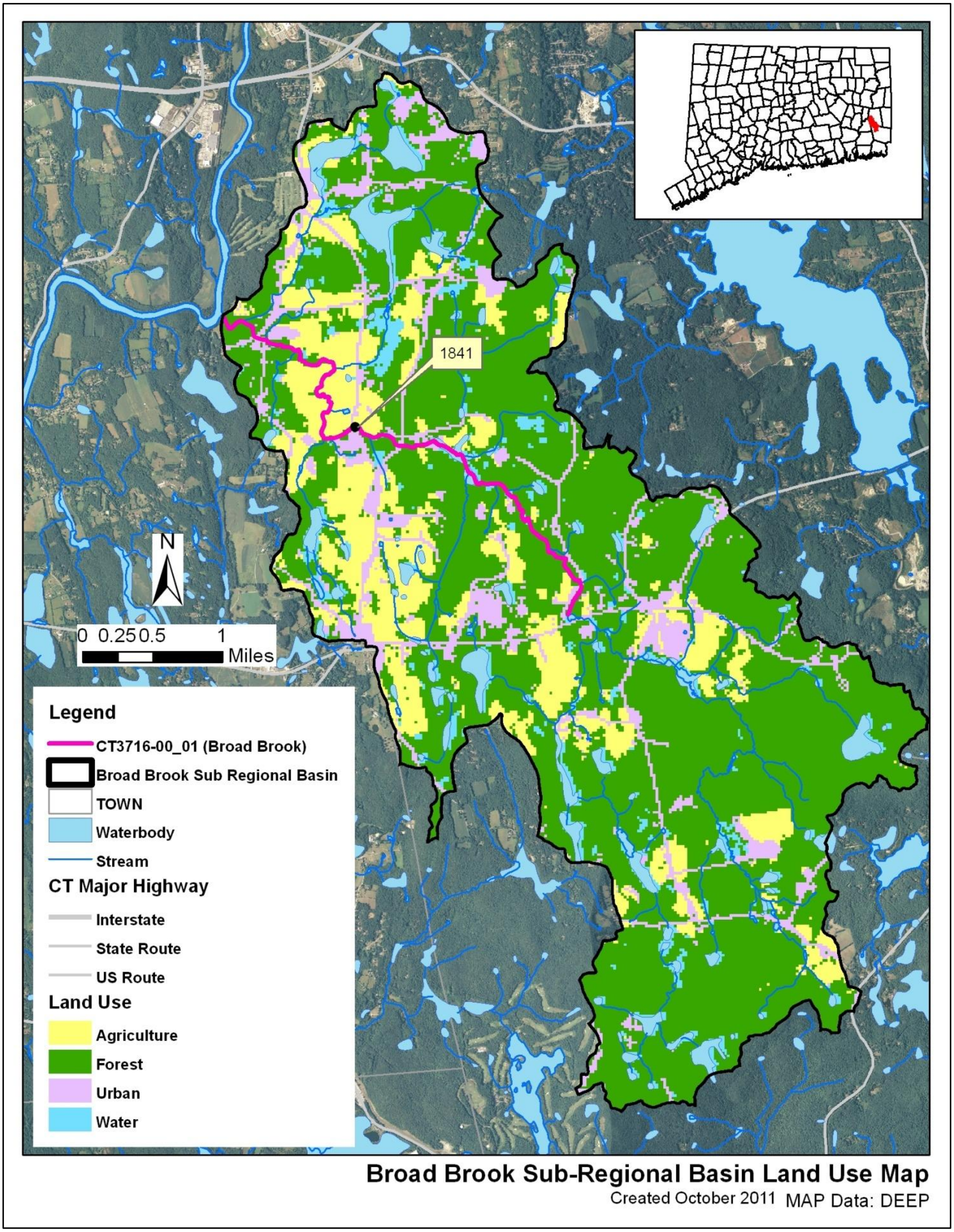


Figure 4: GIS map featuring land use for the Broad Brook watershed at the sub-regional level



WHY IS A TMDL NEEDED?

E. coli is the indicator bacteria used for comparison with the CT State criteria in the CT Water Quality Standards (WQS) (CTDEEP, 2011). All data results are from CT DEEP, USGS, Bureau of Aquaculture, or volunteer monitoring efforts at stations located on the impaired segments.

Table 2: Sampling station location description for the impaired segment in the Broad Brook watershed

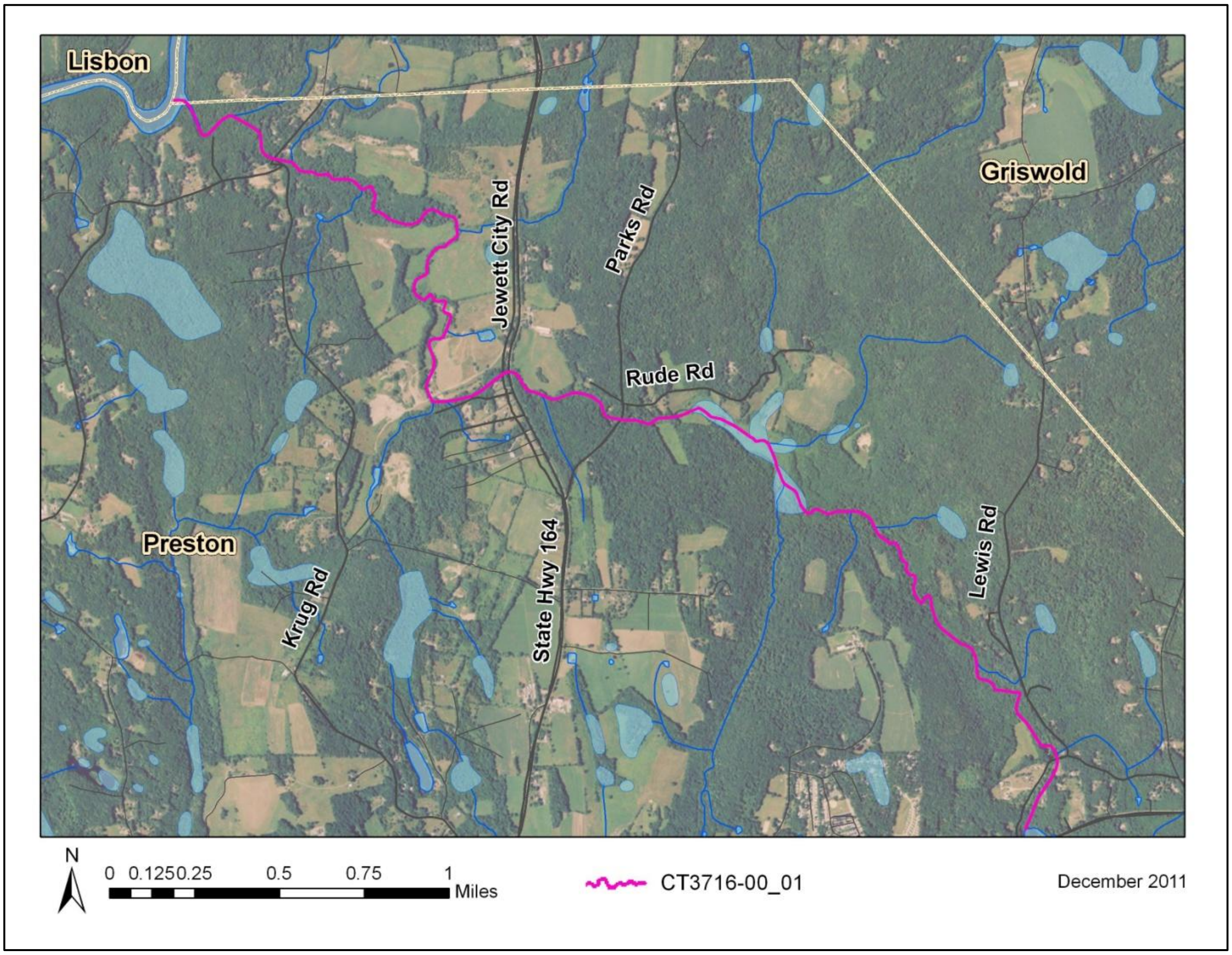
Waterbody ID	Waterbody Name	Station	Station Description	Municipality	Latitude	Longitude
CT3716-00_01	Broad Brook	1841	Route 164	Preston	41.553848	-71.970306

The impaired segment of Broad Brook (CT3716-00_01) is a Class A freshwater river (Figure 5). Its applicable designated uses are a potential drinking water supply area, habitat for fish and other aquatic life and wildlife, recreation, and industrial and agricultural water supply. Water quality analyses were conducted using data from one sampling location (Station 1841) from 2006-2009 (Table 2). The water quality criteria for *E. coli*, along with bacteria sampling results from 2006-2009, are presented in Table 5. The geometric mean exceeded the WQS for *E. coli* in all sampling years, and the single sample values for Station 1841 exceeded the WQS for *E. coli* on multiple dates each year.

To aid in identifying possible bacteria sources, the geometric mean was also calculated for each station for wet-weather and dry-weather sampling days, where appropriate (Table 5). For Broad Brook, geometric means exceeded the WQS for *E. coli* during both wet and dry-weather. Geometric means during wet-weather were higher than dry-weather.

Due to the elevated bacteria measurements presented in Table 5, this impaired segment did not meet CT's bacteria WQS, was identified as impaired, and was placed on the CT List of Waterbodies Not Meeting Water Quality Standards, also known as the CT 303(d) Impaired Waters List. The Clean Water Act requires that all 303(d) listed waters undergo a TMDL assessment that describes the impairments and identifies the measures needed to restore water quality. The goal is for all waterbodies to comply with State WQS.

Figure 5: Aerial map of Broad Brook



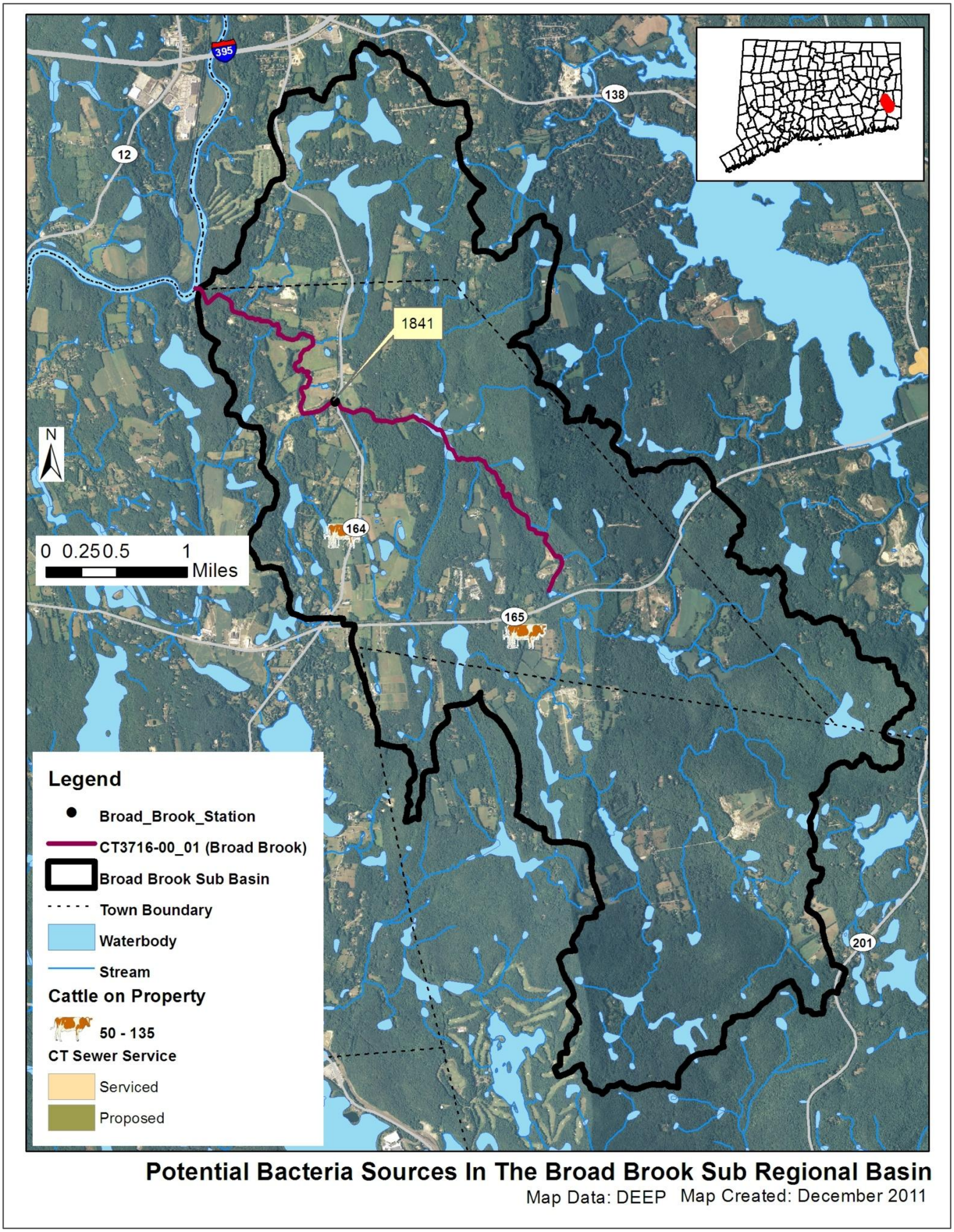
POTENTIAL BACTERIA SOURCES

Potential sources of indicator bacteria in a watershed include point and non-point sources, such as stormwater runoff, agriculture, sanitary sewer overflows (collection system failures), illicit discharges, and inappropriate discharges to the waterbody. Potential sources that have been tentatively identified in the watershed based on land use (Figures 3 and 4) and a collection of local information for the impaired waterbody is presented in Table 3 and Figure 6. However, the list of potential sources is general in nature and should not be considered comprehensive. There may be other sources not listed here that contribute to the observed water quality impairment in the study segments. Further monitoring and investigation will confirm listed sources and discover additional ones. Some segments in this watershed are currently listed as unassessed by CT DEEP procedures. This does not suggest that there are no potential issues on this segment, but indicates a lack of current data to evaluate the segment as part of the assessment process. For some segments, there are data from permitted sources, and CT DEEP recommends that any elevated concentrations found from those permitted sources be addressed through voluntary reduction measures. More detailed evaluation of potential sources is expected to become available as activities are conducted to implement these TMDLs.

Table 3: Potential bacteria sources to the impaired segment of the Broad Brook

Impaired Segment	Permit Source	Illicit Discharge	CSO/SSO Issue	Failing Septic System	Agricultural Activity	Stormwater Runoff	Nuisance Wildlife/Pets	Other
Broad Brook CT3716-00_01				x	x	x	x	

Figure 6: Potential sources in the Broad Brook watershed at the sub-regional level



The potential sources map for the impaired basin was developed after thorough analysis of available data sets. If information is not displayed in the map, then no sources were discovered during the analysis. The following is the list of potential sources that were evaluated: problems with migratory waterfowl, golf course locations, reservoirs, proposed and existing sewer service, cattle farms, poultry farms, permitted sources of bacteria loading (surface water discharge, MS4 permit, industrial stormwater, commercial stormwater, groundwater permits, and construction related stormwater), and leachate and discharge sources (agricultural waste, CSOs, failing septic systems, landfills, large septic tank leach fields, septage lagoons, sewage treatment plants, and water treatment or filter backwash).

Point Sources

Permitted sources within the watershed that could potentially contribute to the bacteria loading are identified in Table 4. This table includes permit types that may or may not be present in the impaired watershed. Currently, no active permits have been issued in the watershed. Additional investigation and monitoring may reveal the presence of additional discharges in the watershed.

Table 4: General categories list of other permitted discharges

Permit Code	Permit Description Type	Number in watershed
CT	Surface Water Discharges	0
GPL	Discharge of Swimming Pool Wastewater	0
GSC	Stormwater Discharge Associated with Commercial Activity	0
GSI	Stormwater Associated with Industrial Activity	0
GSM	Part B Municipal Stormwater MS4	0
GSN	Stormwater Registration – Construction	0
LF	Groundwater Permit (Landfill)	0
UI	Underground Injection	0

Permitted Sources

Since the MS4 permits are not targeted to a specific location, but the geographic area of the regulated municipality, there is no one accurate location on the map to display the location of these permits. One dot will be displayed at the geographic center of the municipality as a reference point. Sometimes this location falls outside of the targeted watershed and therefore the MS4 permit will not be displayed in the Potential Sources Map. Using the municipal border as a guideline will show which areas of an affected watershed are covered by an MS4 permit.

Municipal Stormwater Permitted Sources

Per the EPA Phase II Stormwater rule all municipal storm sewer systems (MS4s) operators located within US Census Bureau Urbanized Areas (UAs) must be covered under MS4 permits regulated by the appropriate State agency. There is an EPA waiver process that municipalities can apply for to not participate in the MS4 program. In Connecticut, EPA has granted such waivers to 19 municipalities. All participating municipalities within UAs in Connecticut are currently regulated under MS4 permits by CT DEEP staff in the MS4 program.

The US Census Bureau defines a UA as a densely settled area that has a census population of at least 50,000. A UA generally consists of a geographic core of block groups or blocks that exceeds the 50,000 people threshold and has a population density of at least 1,000 people per square mile. The UA will also include adjacent block groups and blocks with at least 500 people per square mile. A UA consists of all or part of one or more incorporated places and/or census designated places, and may include additional territory outside of any place. (67 FR 11663)

For the 2000 Census a new geographic entity was created to supplement the UA blocks of land. This created a block known as an Urban Cluster (UC) and is slightly different than the UA. The definition of a UC is a densely settled area that has a census population of 2,500 to 49,999. A UC generally consists of a geographic core of block groups or blocks that have a population density of at least 1,000 people per square mile, and adjacent block groups and blocks with at least 500 people per square mile. A UC consists of all or part of one or more incorporated places and/or census designated places; such a place(s) together with adjacent territory; or territory outside of any place. The major difference is the total population cap of 49,999 people for a UC compared to >50,000 people for a UA. (67 FR 11663)

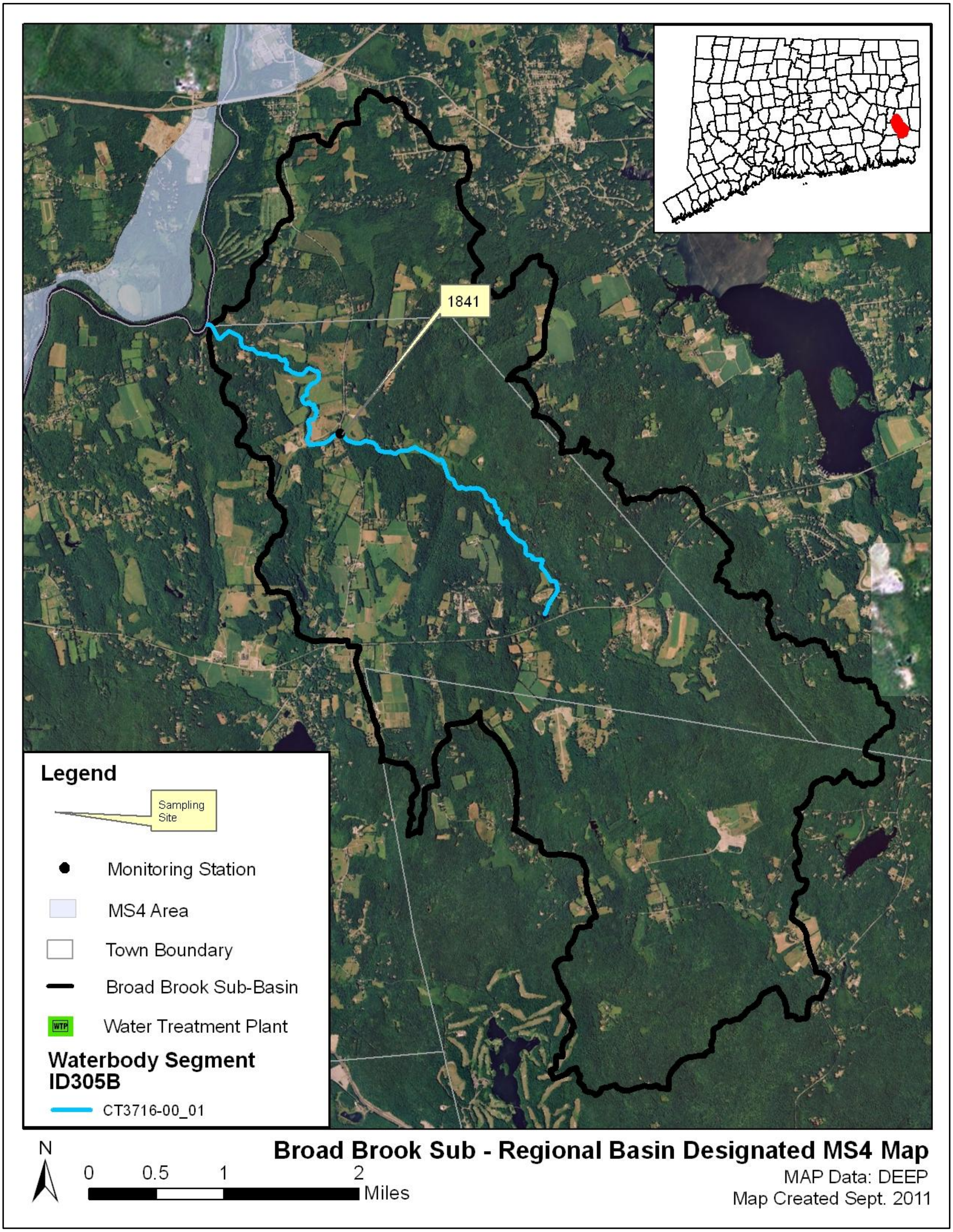
While it is possible that CT DEEP will be expanding the reach of the MS4 program to include UC municipalities in the near future they are not currently under the permit. However, the GIS layers used to create the MS4 maps in this Statewide TMDL did include both UA and UC blocks. This factor creates some municipalities that appear to be within an MS4 program that are not currently regulated through an MS4 permit. This oversight can explain a municipality that is at least partially shaded grey in the maps and there are no active MS4 reporting materials or information included in the appropriate appendix. While these areas are not technically in the MS4 permit program, they are still considered urban by the cluster definition above and are likely to contribute similar stormwater discharges to affected waterbodies covered in this TMDL.

As previously noted, EPA can grant a waiver to a municipality to preclude their inclusion in the MS4 permit program. One reason a waiver could be granted is a municipality with a total population less than 1000 people, even if the municipality was located in a UA. There are 19 municipalities in Connecticut that have received waivers, this list is: Andover, Bozrah, Canterbury, Coventry, East Hampton, Franklin, Haddam, Killingworth, Litchfield, Lyme, New Hartford, Plainfield, Preston, Salem, Sherman, Sprague, Stafford, Washington, and Woodstock. There will be no MS4 reporting documents from these towns even if they are displayed in an MS4 area in the maps of this document.

The list of US Census UCs is defined by geographic regions and is named for those regions, not necessarily by following municipal borders. In Connecticut, the list of UCs includes blocks in the following Census Bureau regions: Colchester, Danielson, Lake Pocotopaug, Plainfield, Stafford, Storrs, Torrington, Willimantic, Winsted, and the border area with Westerly, RI (67 FR 11663). Any MS4 maps showing these municipalities may show grey areas that are not currently regulated by the CT DEEP MS4 permit program.

The Broad Brook watershed is located primarily within the Towns of Preston, Griswold, and Stonington, CT. These towns do not have designated urban areas, as defined by the U.S. Census Bureau, within the watershed and are not required to comply with the General Permit for the Discharge of Stormwater from Small Municipal Storm Sewer Systems (MS4 permit) issued by the Connecticut Department of Energy and Environmental Protection (DEEP) (Figure 7). This general permit is only applicable to municipalities that are identified in Appendix A of the MS4 permit that contain designated urban areas and discharge stormwater via a separate storm sewer system to surface waters of the State. The permit requires municipalities to develop a Stormwater Management Plan (SMP) to reduce the discharge of pollutants as well as to protect water quality. The MS4 permit is discussed further in the "TMDL Implementation Guidance" section of the core TMDL document. Additional information regarding stormwater management and the MS4 permit can be obtained on CTDEEP's website (http://www.ct.gov/dep/cwp/view.asp?a=2721&q=325702&depNav_GID=1654).

Figure 7: MS4 areas of the Broad Brook watershed



Non-point Sources

Non-point source pollution (NPS) comes from many diffuse sources and is more difficult to identify and control. NPS pollution is often associated with land-use practices. Examples of NPS that can contribute bacteria to surface waters include insufficient septic systems, pet and wildlife waste, agriculture, and contact recreation (swimming or wading). Potential sources of NPS within the Broad Brook watershed are described below.

Agricultural Activities

Agricultural operations are an important economic activity and landscape feature in many areas of the State. Runoff from agricultural fields may contain pollutants such as bacteria and nutrients (USEPA, 2011a). This runoff can include pollutants from farm practices such as storing manure, allowing livestock to wade in nearby waterbodies, applying fertilizer, and reducing the width of vegetated buffer along the shoreline. Agricultural land use occupies approximately 16% of the watershed and is concentrated near the impaired segment (Figure 4). In particular, two large cattle operations are located near the impaired segment on Routes 165 and 164 (Figure 6). As shown in Table 5, the geometric mean during wet-weather at Station 1841 exceeded the WQS for *E.* coli. A high geometric mean for bacteria during wet-weather may indicate that stormwater runoff, including runoff from agricultural operations, may be contributing bacteria to nearby waterbodies. As such, agricultural runoff from these farms and others in the area is a potential source of bacteria to Broad Brook.

Insufficient Septic Systems

As shown in Figure 6, the entire Broad Brook watershed relies on onsite wastewater treatment systems, such as septic systems. Properly managed septic systems and leach fields have the ability to effectively remove bacteria from waste. If systems are not maintained, waste will not be adequately treated and may result in bacteria reaching nearby surface and ground water. As shown in Table 5, the geometric mean for *E. coli* bacteria exceeded the WQS at Station 1841 during dry-weather. A high geometric mean for bacteria during dry-weather may indicate that illicit discharges, such as insufficient septic systems, may be contributing bacteria to nearby waterbodies. In Connecticut, local health directors or health districts are responsible for keeping track of any reported insufficient or failing septic systems in a specific municipality. The Town of Preston has a part-time health director (http://www.preston-ct.org/html/town_directory.html). The Town of North Stonington has a part-time health director (http://www.northstoningtonct.gov/Pages/NStoningtonCT_Dept/Health/index). The Towns of Griswold and Lisbon do not have specific health directors and are part of the Uncas Health District (http://www.uncashd.org/).

Wildlife and Domestic Animal Waste

Wildlife and domestic animals within the Broad Brook watershed represent another potential source of bacteria. With the construction of roads and drainage systems, these wastes may no longer be retained on the landscape, but instead may be conveyed via stormwater to the nearest surface water. These physical land alterations can exacerbate the impact of natural sources on water quality (USEPA, 2001). As the majority of the watershed is undeveloped, particularly upstream of the impaired segment in the Pachaug State Forest, wildlife waste is a potential source of bacteria to Broad Brook. Developed portions of the watershed that tend to follow major highways are characterized by residential development. Waste from domestic animals, such as dogs, may also be contributing to bacteria concentrations in Broad Brook.

Stormwater Runoff from Developed Areas

The majority of the Broad Brook watershed is undeveloped. Approximately 11% of the land use in the watershed is considered urban, and this area is concentrated along major highways in the watershed (Figures 2 and 9). Urban areas are often characterized by impervious cover, or surface areas such as roofs and roads that force water to run off land surfaces rather than infiltrate into the soil. Studies have shown a link between increasing impervious cover and degrading water quality conditions in a watershed (CWP, 2003). In one study, researchers correlated the amount of fecal coliform to the percent of impervious cover in a watershed (Mallin *et al.*, 2000). The entire watershed has between 0 – 6% impervious surfaces (Figure 8).

Additional Sources

There may be other sources not listed here or identified in Figure 6 that contribute to the observed water quality impairment in the Broad Brook watershed. Further monitoring and investigation will confirm listed sources and discover additional ones. More detailed evaluation of potential sources is expected to become available as activities are conducted to implement this TMDL.

Land Use/Landscape

Riparian Buffer Zones

The riparian buffer zone is the area of land located immediately adjacent to streams, lakes, or other surface waters. The boundary of the riparian zone and the adjoining uplands is gradual and not always well-defined. However, riparian zones differ from uplands because of high levels of soil moisture, frequent flooding, and the unique assemblage of plant and animal communities found there. Through the interaction of their soils, hydrology, and vegetation, natural riparian areas influence water quality as contaminants are taken up into plant tissues, adsorbed onto soil particles, or modified by soil organisms. Any change to the natural riparian buffer zone can reduce the effectiveness of the natural buffer and has the potential to contribute to water quality impairment (USEPA, 2011b).

The CLEAR program at UCONN has created streamside buffer layers for the entire State of Connecticut (http://clear.uconn.edu/), which have been used in this TMDL. Analyzing this information can reveal potential sources and implementation opportunities at a localized level. The land use directly adjacent to a waterbody can have direct impacts on water quality from surface runoff sources.

The riparian zones of the impaired segment of Broad Brook are characterized by agricultural areas with some forested and developed areas (Figure 9). If not properly treated, runoff from agricultural fields may contain pollutants such as bacteria and nutrients.

Figure 8: Impervious cover (%) for the Broad Brook sub-regional watershed

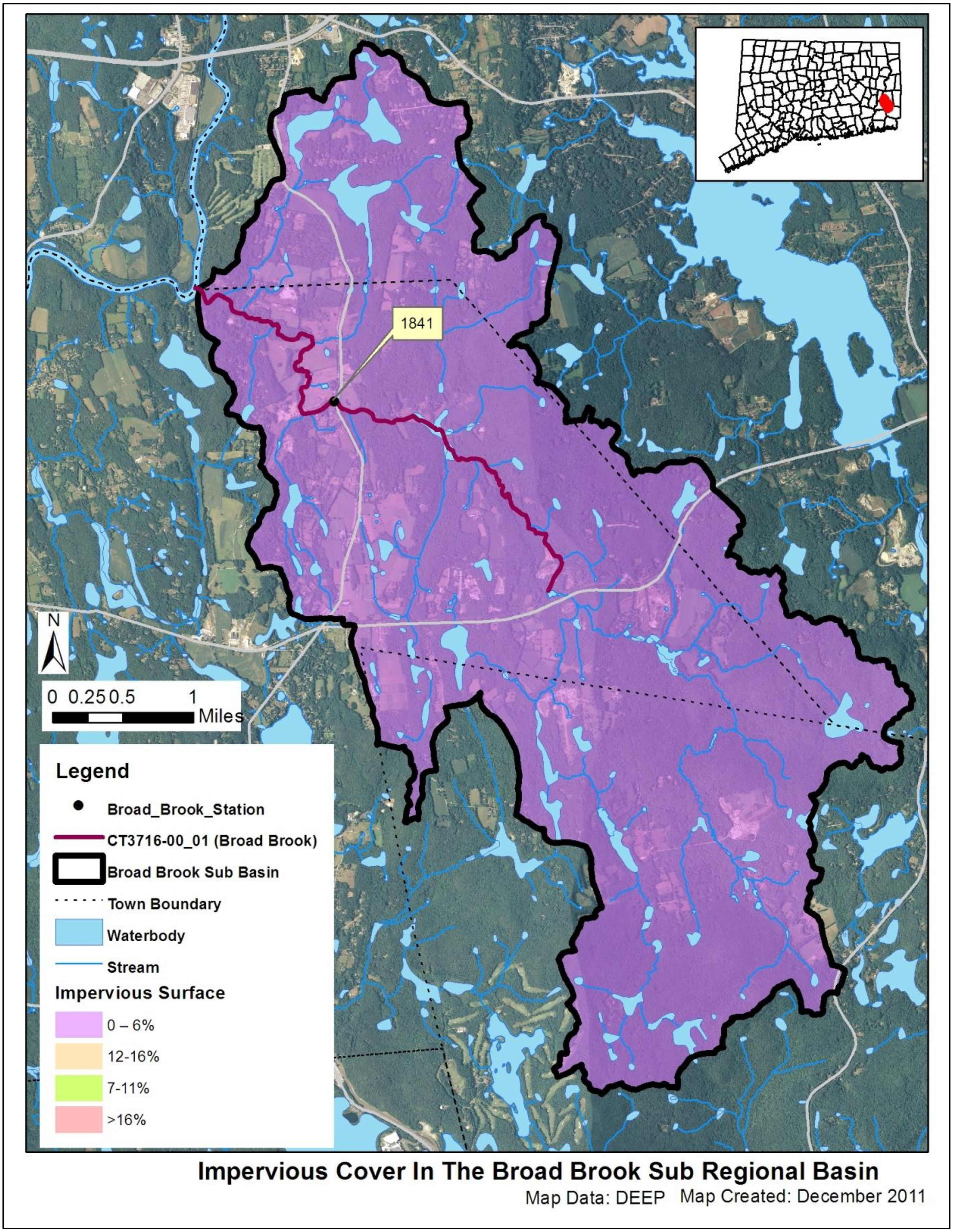
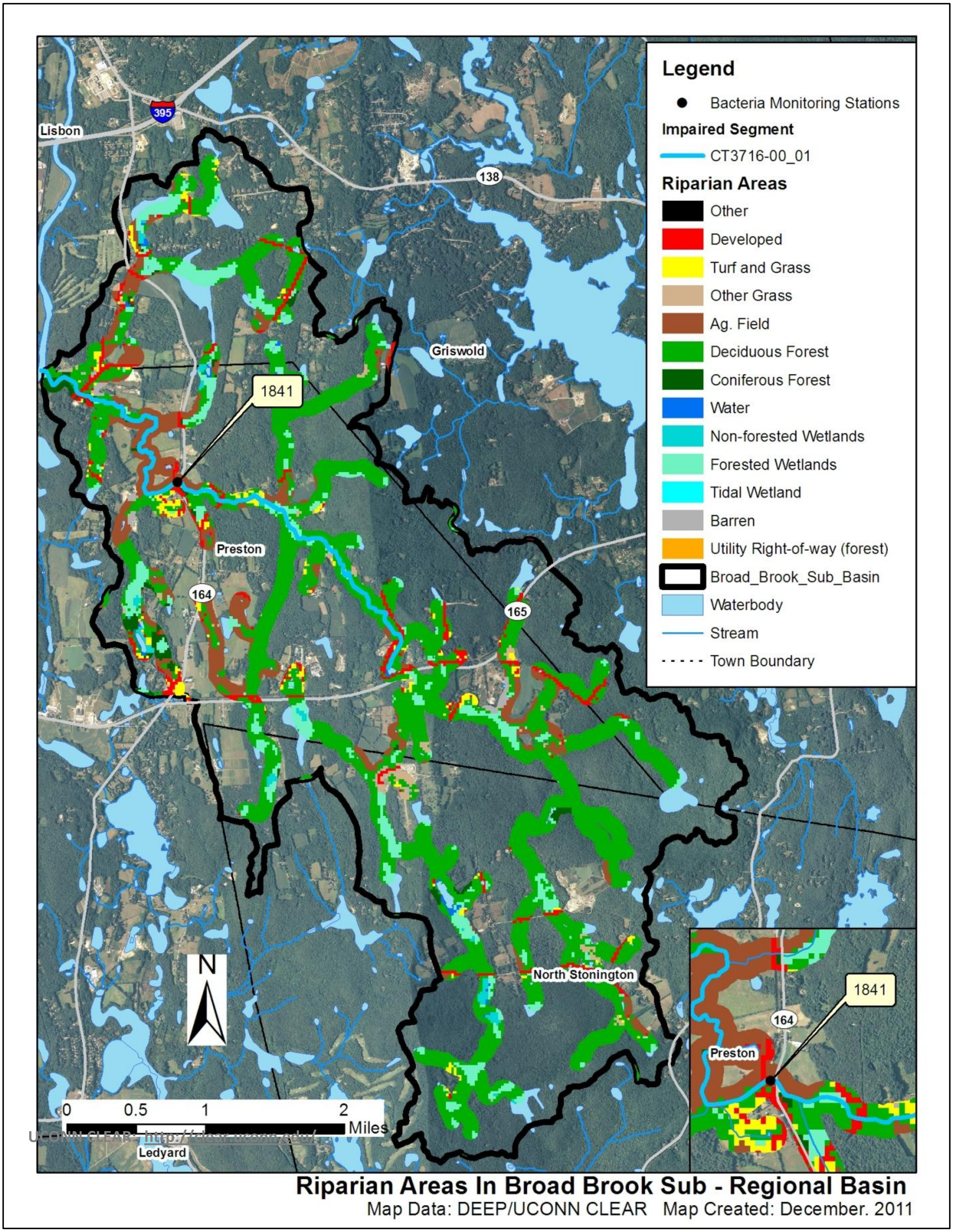


Figure 9: Riparian buffer zone information for the Broad Brook watershed



RECOMMENDED NEXT STEPS

Future mitigative activities are necessary to ensure the long-term protection of Broad Brook and have been prioritized below.

1) Ensure there are sufficient buffers on agricultural lands along Broad Brook.

If not already in place, agricultural producers should work with the CT Department of Agriculture and the U.S. Department of Agriculture Natural Resources Conservation Service to develop conservation plans for their farming activities within the watershed. These plans should focus on ensuring that there are sufficient stream buffers, that fencing exists to restrict livestock and horse access to streams and wetlands, and that animal waste handling, disposal, and other appropriate Best Management Practices (BMPs) are in place. Particular attention should be paid to those agricultural operations located near the impaired segment of Broad Brook, particularly the two cattle operations along Routes 164 and 165 (Figures 4 and 6).

2) Develop a system to monitor septic systems.

All residents of the Broad Brook watershed rely on septic systems. If not already in place, the watershed towns should establish a program to ensure that existing septic systems are properly operated and maintained. For instance, communities can create an inventory of existing septic systems through mandatory inspections. Inspections help encourage proper maintenance and identify failed and sub-standard systems. Policies that govern the eventual replacement of the sub-standard systems within a reasonable timeframe could also be adopted. Towns can also develop programs to assist citizens with the replacement and repair of older and failing systems.

3) Evaluate municipal education and outreach programs regarding animal waste.

Any education and outreach program in the watershed should highlight the importance of not feeding waterfowl and wildlife and managing waste from horses, dogs, and other pets. The towns and residents can take measures to minimize waterfowl-related impacts such as allowing tall, coarse vegetation to grow in the riparian areas of the impaired segments that are frequented by waterfowl. Waterfowl, especially grazers like geese, prefer easy access to water. Maintaining an uncut vegetated buffer along the shore will make the habitat less desirable to geese and encourage migration. In addition, any educational program should emphasize that feeding waterfowl, such as ducks, geese, and swans, may contribute to water quality impairments in the Broad Brook watershed and can harm human health and the environment.

Animal wastes should be disposed of away from any waterbody or storm drain system. BMPs effective at reducing the impact of animal waste on water quality include installing signage, providing pet waste receptacles in high-uses areas, enacting ordinances requiring the clean-up of pet waste, and targeting educational and outreach programs in problem areas.

4) Identify areas in the Broad Brook watershed to implement Low Impact Development (LID) and Best Management Practices (BMPs) to control stormwater runoff.

As noted previously, towns within the Broad Brook watershed are not MS4 communities and are not regulated by the MS4 program. However, 11% of the watershed is considered urban and portions near the impaired segment of the Broad Brook are developed. Therefore, stormwater runoff may still be contributing bacteria to the waterbody. To identify specific areas that are contributing bacteria to the impaired segment, the Town of Preston should conduct wet-weather sampling at stormwater outfalls that discharge directly to Broad Brook. To treat stormwater runoff, the town should also identify areas along the more developed sections of the brook, particularly near Station 1841, to install BMPs designed to encourage stormwater to infiltrate into the ground before entering Broad Brook. These BMPs would disconnect impervious areas and reduce pollutant loads to the river. More detailed information and BMP recommendations can be found in the core TMDL document.

Towns that are not MS4 communities could also choose to adopt the 6 minimum measures required under the MS4 permit. Though not required, adopting these minimum measures would provide a framework for addressing areas of the watershed that may be contributing bacteria through stormwater runoff. The MS4 General Permit is required for any municipality with urbanized areas that initiates, creates, originates or maintains any discharge of stormwater from a storm sewer system to waters of the State. The MS4 permit requires towns to design a Stormwater Management Plan (SMP) to reduce the discharge of pollutants in stormwater to improve water quality. The plan must address the following 6 minimum measures:

1. Public Education and Outreach
2. Public Involvement/Participation
3. Illicit discharge detection and elimination
4. Construction site stormwater runoff control
5. Post-construction stormwater management in the new development and redevelopment
6. Pollution prevention/good housekeeping for municipal operations

BACTERIA DATA AND PERCENT REDUCTIONS TO MEET THE TMDL

Table 5: Broad Brook Bacteria Data

Waterbody ID: CT3716-00_01

Characteristics: Freshwater, Class A, Potential Public Drinking Water Supply, Habitat for Fish and other Aquatic Life and Wildlife, Recreation, and Industrial and Agricultural Water Supply

Impairment: Recreation (*E. coli bacteria)*

Water Quality Criteria for E. coli:

Geometric Mean: 126 colonies/100 mL

Single Sample: 410 colonies/100ml

Percent Reduction to meet TMDL:

Geometric Mean: **71%**

Single Sample: **98%**

Data: 2006 - 2009 from CT DEEP targeted sampling efforts, 2012 TMDL Cycle

Single sample *E. coli* data (colonies/100 mL) from Station 1841 on Broad Brook with annual geometric means calculated

Station Name	Station Location	Date	Results	Wet/Dry	Geomean
1841	Route 164 crossing	6/21/2006	270	dry	248
1841	Route 164 crossing	6/28/2006	775†	dry	
1841	Route 164 crossing	7/3/2006	200	dry	
1841	Route 164 crossing	7/11/2006	190	dry	
1841	Route 164 crossing	7/18/2006	190	dry	
1841	Route 164 crossing	7/27/2006	220	dry	
1841	Route 164 crossing	8/2/2006	220	dry	
1841	Route 164 crossing	8/9/2006	190	dry	
1841	Route 164 crossing	8/16/2006	805†	wet	
1841	Route 164 crossing	8/23/2006	190†	dry	
1841	Route 164 crossing	9/11/2006	104†	dry	

Single sample *E. coli* data (colonies/100 mL) from Station 1841 on Broad Brook with annual geometric means calculated (continued)

Station Name	Station Location	Date	Results	Wet/Dry	Geomean
1841	Route 164 crossing	6/6/2007	315†	wet	331
1841	Route 164 crossing	6/13/2007	340	dry	
1841	Route 164 crossing	6/20/2007	150	dry	
1841	Route 164 crossing	7/11/2007	390	dry	
1841	Route 164 crossing	7/19/2007	990	wet	
1841	Route 164 crossing	7/26/2007	700	dry	
1841	Route 164 crossing	8/9/2007	20	wet	
1841	Route 164 crossing	8/23/2007	63	wet	
1841	Route 164 crossing	9/4/2007	120	dry	
1841	Route 164 crossing	9/12/2007	**24000* (98%)**	wet	
1841	Route 164 crossing	6/4/2008	820	wet**	**429* (71%)**
1841	Route 164 crossing	6/11/2008	335†	dry**	
1841	Route 164 crossing	6/19/2008	660	dry**	
1841	Route 164 crossing	6/25/2008	290	wet**	
1841	Route 164 crossing	7/2/2008	250	dry**	
1841	Route 164 crossing	7/9/2008	240†	dry**	
1841	Route 164 crossing	7/16/2008	350	dry**	
1841	Route 164 crossing	7/23/2008	750	wet**	
1841	Route 164 crossing	7/30/2008	580	dry**	
1841	Route 164 crossing	8/6/2008	880	wet**	
1841	Route 164 crossing	8/13/2008	520	dry**	
1841	Route 164 crossing	8/21/2008	176†	dry**	

Single sample *E. coli* data (colonies/100 mL) from Station 1841 on Broad Brook with annual geometric means calculated (continued)

Station Name	Station Location	Date	Results	Wet/Dry	Geomean
1841	Route 164 crossing	6/3/2009	260	dry**	389
1841	Route 164 crossing	6/11/2009	660	wet**	
1841	Route 164 crossing	6/25/2009	200	dry**	
1841	Route 164 crossing	7/1/2009	820†	wet**	
1841	Route 164 crossing	7/9/2009	520	wet	
1841	Route 164 crossing	7/16/2009	350	dry	
1841	Route 164 crossing	7/23/2009	380	wet	
1841	Route 164 crossing	7/29/2009	290	dry	
1841	Route 164 crossing	8/6/2009	300	dry	
1841	Route 164 crossing	8/13/2009	680	dry	
1841	Route 164 crossing	8/20/2009	269†	dry	

Shaded cells indicate an exceedance of water quality criteria

†Average of two duplicate samples

**** Weather conditions for selected data taken from Hartford because local station had missing data**

***Indicates single sample and geometric mean values used to calculate the percent reduction**

Wet and dry weather *E. coli* (colonies/100 mL) geometric mean values for Station 1841 on Broad Brook

Station Name	Station Location	Years Sampled	Number of Samples		Geometric Mean		
			Wet	Dry	All	Wet	Dry
1841	Route 164 crossing	2006-2009	17	37	330	535	265

Shaded cells indicate an exceedance of water quality criteria

Weather condition determined from rain gages at Norwich Public Utility Plant in Norwich, CT and at Hartford Bradley International Airport

References

Costa, Joe (2011). Calculating Geometric Means. Buzzards Bay National Estuary Program. **Online**: http://www.buzzardsbay.org/geomean.htm

CTDEEP (2010). State of Connecticut Integrated Water Quality Report. **Online:** http://www.ct.gov/dep/lib/dep/water/water_quality_management/305b/ctiwqr10final.pdf

CTDEEP (2011). State of Connecticut Water Quality Standards. **Online:** http://www.ct.gov/dep/lib/dep/water/water_quality_standards/wqs_final_adopted_2_25_11.pdf

CWP (2003). Impacts of Impervious Cover on Aquatic Systems. Center for Watershed Protection. **Online**: http://clear.uconn.edu/projects/tmdl/library/papers/Schueler_2003.pdf

Federal Register 67 (March 15, 2002) 11663-11670. Urban Area Criteria for Census 2000.

Mallin, M.A., K.E. Williams, E.C. Escham, R.P. Lowe (2000). Effect of Human Development on Bacteriological Water Quality in Coastal Wetlands. Ecological Applications 10: 1047-1056.

USEPA (2001). Managing Pet and Wildlife Waste to Prevent Contamination of Drinking Water. **Online**: http://www.epa.gov/safewater/sourcewater/pubs/fs_swpp_petwaste.pdf.

USEPA (2011a). Managing Nonpoint Source Pollution from Agriculture. **Online:** http://water.epa.gov/polwaste/nps/outreach/point6.cfm

USEPA (2011b). Riparian Zone and Stream Restoration. **Online:** http://epa.gov/ada/eco/riparian.html

USEPA (2011c). Land Use Impacts on Water. **Online:** http://epa.gov/greenkit/toolwq.htm